Energy, Mines and Resources Canada
Energie, Mines et Ressources Canada

CANMET
Canada Centre for Mineral and Energy Technology
Centre canadien de la technologie des minéraux et de l'énergie

# STRESS DETERMINATION AT DETOUR LAKE MINE, NORTHERN ONTARIO

B. ARJANG AND G. HERGET

ELLIOT LAKE LABORATORY

APRIL 1985

This document is an unedited [illegible] prepared primarily [illegible] for the purpose [illegible] of the Canada [illegible] (CANMET)

Ce document est un rapport [illegible] principalement pour [illegible] de diffusion [illegible] (CANMET)

MICROMEDIA

DEC 11 [illegible]

MINERALS RESEARCH PROGRAM
MINING RESEARCH LABORATORIES
DIVISION REPORT MRP/MRL 85-77 (TR)

# STRESS DETERMINATIONS AT DETOUR LAKE MINE, NORTHERN ONTARIO

by

B. Arjang* and G. Herget**

## ABSTRACT

Field stress determinations were performed at the Detour Lake Mine, Northern Ontario. Elastic strain recoveries were measured at depths of 60 to 85 m below surface using CSIR four-gauge biaxial strain cells (doorstopper). The results indicated a maximum stress in an east to northeast direction. The orientation of the principal compressive stresses with respect to true north (= Mine grid north) were:

| Principal Stress | Direction | Plunge |
|---|---|---|
| $\sigma_1$ | WSW-ENE | 32° WSW |
| $\sigma_2$ | NNW-SSE | 02° NNW |
| $\sigma_3$ | ENE-WSW | 58° ENE |

The principal stress directions and magnitudes were comparable with the typical data obtained at shallow depths in Northern Ontario.

The maximum pre-mining stress is oriented along the strike of the ore zone.

---

* Research Scientist, Elliot Lake Laboratory, CANMET, Energy, Mines and Resources Canada, Elliot Lake, Ontario.
** Research Scientist, Mining Research Laboratories, CANMET, Energy, Mines and Resources Canada, Ottawa, Ontario.

# DÉTERMINATION DES CONTRAINTES À LA MINE DETOUR LAKE DU NORD DE L'ONTARIO

par

B. Arjang* et G. Herget**

## Résumé

On a effectué la détermination des champs de contrainte à la mine Detour Lake du Nord de l'Ontario. Le rendement des déformations élastiques a été mesuré à une profondeur de 60 à 80 m sous la surface, à l'aide de quatres cellules de déformation biaxes à jauges du CSIR (Council of Scientific and Industrial Research). Les résultats ont indiqué une contrainte maximum allant dans le sens est à nord-est. L'orientation des contraintes principales de compression quant au nord géographique (= nord du quadrillage de la mine) était:

| Contrainte principale | Direction | Plonge |
|---|---|---|
| $\sigma 1$ | O.-S.-O. - E.-N.-E. | 32° O.-S.-O. |
| $\sigma 2$ | N.-N.-O. - S.-S.-E. | 02° N.-N.-O. |
| $\sigma 3$ | E.-N.-E. - O.-S.-O. | 58° E.-N.-E. |

La direction principale et l'amplitude de la contrainte étaient comparables aux données types obtenues au cours de mesures effectuées à peu de profondeur dans le Nord de l'Ontario.

La contrainte maximum avant l'exploitation minière était orientée dans la direction de la zone de minerai.

---

*Chercheur scientifique, Laboratoire d'Elliot Lake, CANMET, Énergie, Mines et Ressources Canada, Elliot Lake (Ontario).

**Chercheur scientifique, Laboratoires de recherche minière, CANMET, Énergie, Mines et Ressources Canada, Ottawa (Ontario).

CONTENTS


| | Page |
|---|---|
| ABSTRACT | i |
| RESUME | ii |
| INTRODUCTION | 1 |
| GEOLOGICAL SETTING | 1 |
| FIELD MEASUREMENTS AND LABORATORY TESTS | 1 |
| STRESS CALCULATIONS | 7 |
| DISCUSSION OF RESULTS | 11 |
| ACKNOWLEDGEMENT | 11 |
| REFERENCES | 12 |


FIGURES


| No. | | |
|---|---|---|
| 1. | Regional geology and the location of Detour Lake Mine | 2 |
| 2. | Four-gauge doorstopper strain cell showing the orientation of the individual gauges with respect to the drill hole direction. | 4 |
| 3. | Location and orientation of test holes | 5 |
| 4. | A, B, C: maximum stress directions in the plane normal to the drill hole axis; D: principal stress directions from stress determinations in three test hole set up | 10 |


TABLES


| | | |
|---|---|---|
| 1. | Strain recovery data from doorstopper tests, Detour Lake Mine | 6 |
| 2. | Magnitudes of maximum and minimum stresses and the direction of maximum stress from doorstopper measurements, Detour Lake Mine. | 8 |
| 3. | Stress components, magnitudes and orientations of the principal stresses from doorstopper measurements, Detour Lake Mine | 9 |

## INTRODUCTION

As a continuation of the stress determination program, a co-operative project was carried out at the Detour Lake Mine, Northern Ontario. Presently the mine is being operated as an open pit. Open pit mining is planned to continue to a depth of 120 m.

A decline to 120 m below surface, drifting, and cross-cutting, were developed for further exploration of the ore zone. On the 120 m level, ground stresses were measured at a depth of 60 to 85 m below the open pit bottom using CSIR four-gauge biaxial strain cells (doorstopper).

## GEOLOGICAL SETTING

The Detour Lake Mine is situated about 200 km northeast of Cochrane in Northern Ontario. Geologically, the mine is located at the northern part of the Abitibi orogenic belt, as shown in Figure 1. The mine, similar to other deposits in the area, reflects a complex history of intermittent faulting and extrusive activity associated with the deposition of the ore. The gold-bearing ore zone is contained primarily in a silicified mafic flow with chert and talc-chlorite. The lenticular ore zones, associated with the east-trending structures, dip steeply to the north and plunge towards the west.

## FIELD MEASUREMENTS AND LABORATORY TESTS

Elastic strain recoveries were measured in the fine-grained rock of the footwall, ore zone, and hanging wall strata using four-gauge biaxial strain cells. The techniques and details of the test procedure for using the strain cells are given in reference (2,3). Figure 2 shows the orientation of the individual gauges of the strain cell with respect to the drill hole direction.

The stress determination sites were selected away from intense

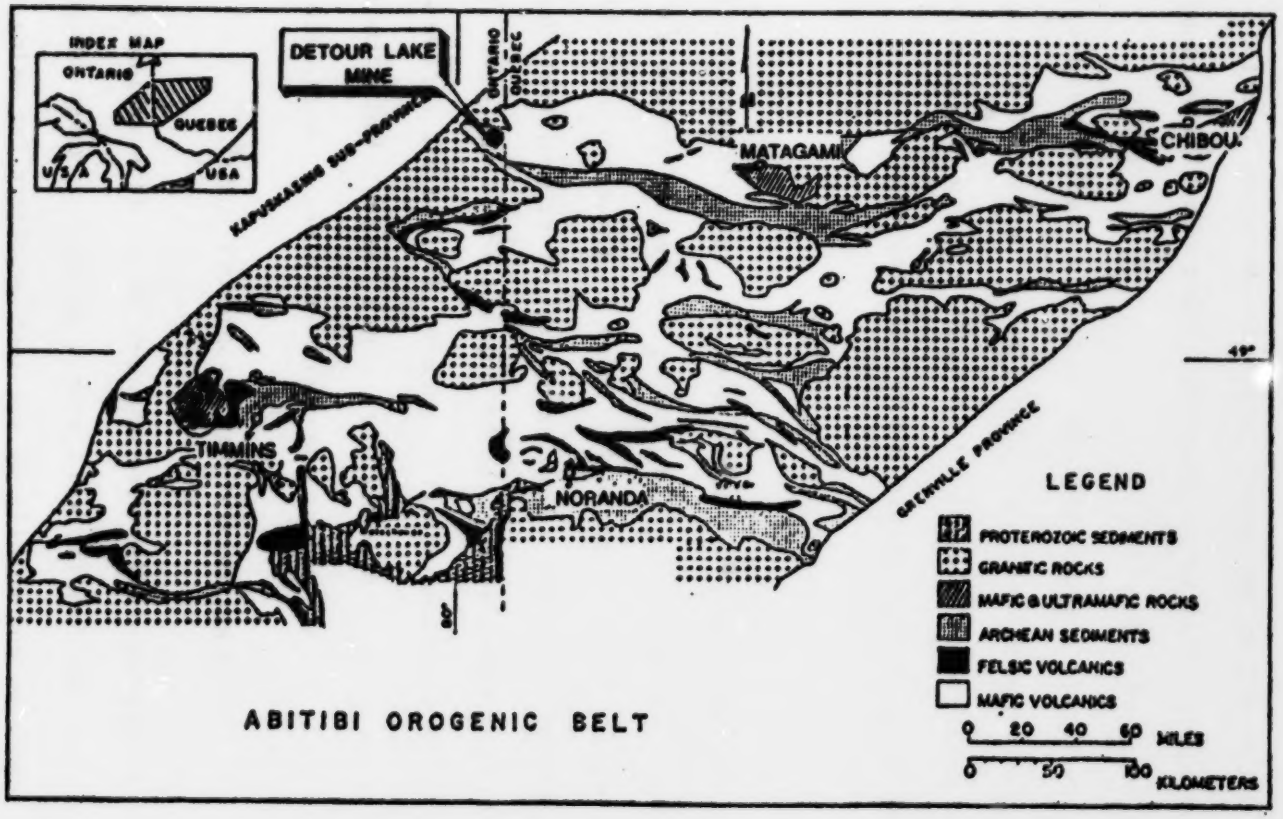



Fig. 1 - Regional geology (1), and the location of Detour Lake Mine.

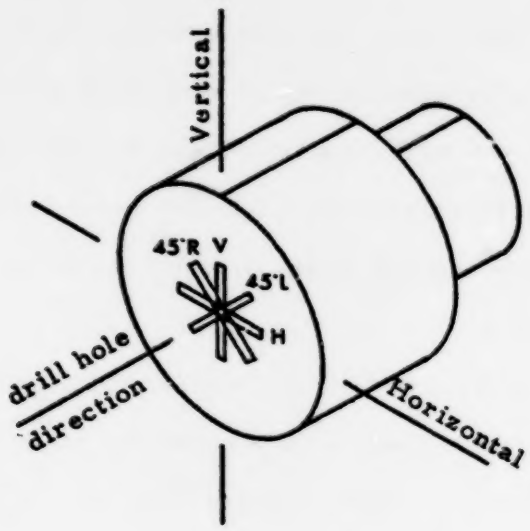
fracturing and faults. The tests were performed in BW-size drill holes (diameter 63 mm), yielding a core with a 44 mm nominal diameter. Five holes were drilled from mine openings which were about 4.0 m square. All the tests were conducted at a minimum depth of 4.50 m from the mine opening. Three tests were attempted in each drill hole, resulting in a total of fifteen tests. The locations and directions of the test holes in the mine grid system are shown in Figure 3.

In the vertical ($+90^{o}$) drill holes (DL1, DL2 and DL3) the vertical gauge of the strain cells was oriented towards north in the mine grid system. The horizontal holes (DL4, DL5) oriented $+1.5^{o}$ to $+1.7^{o}$ above horizontal, were drilled divergent from the same set up to minimize the effects of local stress variations.

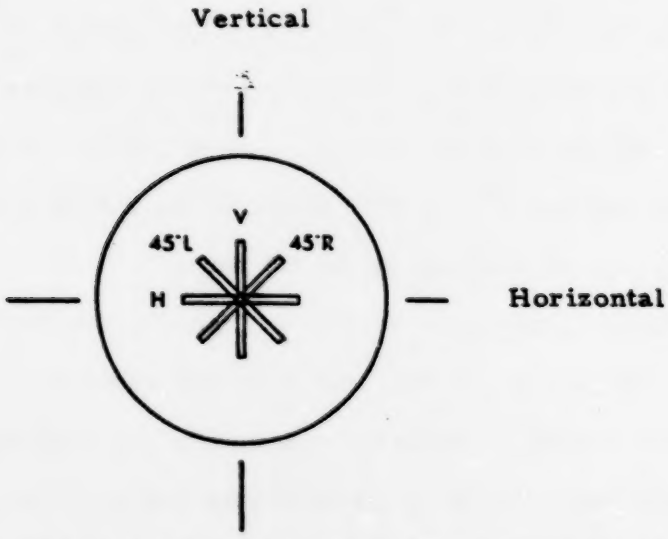
In some tests the presence of talc-chlorite resulted in poor bonding of the strain cells and sufficient cell-rock bonding was not achieved. Some strain cells separated from the overcored samples or the gauges showed unstable readings after overcoring. The extremely low temperature at the test environment (approximately $2^{o}C$) extended the curing time of the strain gauge cement (Philips PR 9244/04) up to 2.5 hours.

Elastic constants were obtained in the laboratory. Three core specimens (diameter $\simeq$44 mm), cut from the remainder of the overcored test pieces, were tested in uniaxial compression for each test hole. Fifteen core samples were tested using a portable rock tester. The mean values determined for elastic modulus and Poisson's ratio are given in Table 1. These values were used for the stress tensor calculations.

The occurrence of a few stringers of quartz-carbonate, recemented fractures and talc-chlorite throughout some overcored test samples resulted in significant variations in the elastic constants obtained.




Four Gauge Doorstopper Strain Cell




Orientation of Strain Gauges Looking down the Drill hole

Fig. 2 - Four gauge doorstopper strain cell (not to scale) showing the orientation of the individual gauges with respect to the drill hole direction.

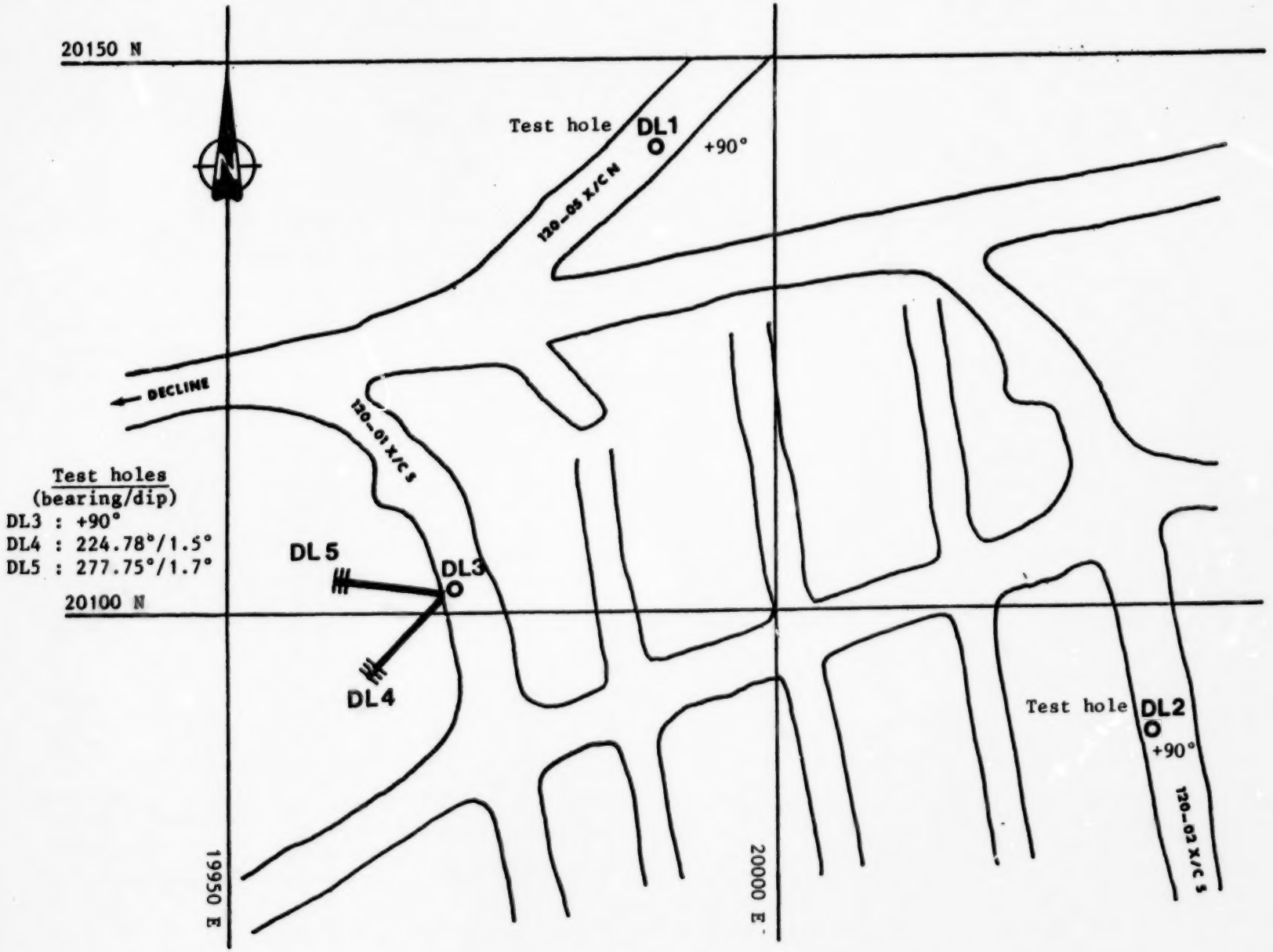



Fig. 3 - Location and orientation of test holes, scale 1:500 (Grid north = True north).

Table 1 - Strain recovery data from doorstopper tests, Detour Lake Mine

| Depth below Surface | Test No. | Depth from Collar (m) | Strain Recovery ($10^{-6}$ in/in) Horiz. $S_1$ | 45°R $S_2$ | Vert. $S_3$ | 45°L $S_4$ | Strain** Invariance | Elastic Modulus (GPa) | Poisson's Ratio | Rock Type |
|---|---|---|---|---|---|---|---|---|---|---|
| 85 m (hanging wall) | DL1-1* | 4.60 | -565 | -513 | -340 | -443 | 51 | 58.65 | 0.26 | Basalt (mafic flow) |
| | DL1-2 | 5.50 | +185 | +39 | +36 | - | - | | | |
| | DL1-3 | 5.80 | +7 | +8 | +6 | +9 | -4 | | | |
| 60 m (orebody) | DL3-1 | 4.50 | +7 | +18 | +25 | +15 | -1 | 65.72 | 0.24 | Silici-fied mafic flow with chert |
| | DL3-2 | 4.90 | +40 | +26 | +36 | +43 | 7 | | | |
| | DL3-3 | 5.20 | +51 | +28 | +15 | +69 | -31 | | | |
| | DL4-1* | 9.40 | -85 | -300 | -70 | -47 | 192 | | | |
| | DL4-2 | 9.70 | +8 | -4 | +7 | +17 | 2 | | | |
| | DL4-3 | 10.00 | +12 | -23 | +3 | +56 | -18 | | | |
| | DL5-1* | 8.80 | -30 | +7 | -3 | -3 | -37 | | | |
| | DL5-2 | 9.30 | -2 | +2 | -5 | - | - | | | |
| | DL5-3 | 9.75 | -2 | - | -5 | -26 | - | | | |
| 60 m (foot-wall) | DL2-1* | 4.60 | -17 | -13 | -10 | -41 | 27 | 47.80 | 0.30 | Talc-Chlorite |
| | DL2-2 | 4.90 | +15 | +22 | +11 | +17 | -13 | | | |
| | DL3-3 | 5.20 | +15 | +9 | +9 | +10 | 5 | | | |

* Test omitted from stress calculations.

** Strain invariance, according to elastic theory (4) : $(S_1 + S_3) - (S_2 + S_4) = 0$.

## STRESS CALCULATIONS

The elastic strain recoveries, the setting depth of the strain cells, and the elastic properties used for stress tensor analyses are given in Table 1. The table also provides the calculated values of strain invariance (differences between the sums of strains recorded for perpendicular gauges) and the overall rock type encountered in the stress measurement sites.

An examination of the strain recovery data indicated that some tests yielded negative strain recoveries, or showed significant differences in strain invariance. The anomalous measurements, which did not seem to fit with the remaining data, were omitted from the stress calculation.

The calculated magnitudes of maximum and minimum stresses and the directions of maximum stresses in vertical holes are given in Table 2. The best fit stress tensor was calculated from three test holes (DL3, DL4 and DL5) set up in the ore zone. Table 3 shows the stress components and the magnitude and orientation of the principal stresses in the mine grid system.

The maximum stress directions for each vertical hole and the principal stress orientations are plotted in Figure 4. The plots show that the maximum stress prevailed in a ENE to NE direction, and only one test (DL3-4) varied considerably from the main trend.

The accuracy of strain indicator used for the measurements was in the range of $\pm$0.1 percent of readings, or about 5 microstrain. In some measurements extremely low elastic strain recoveries were recorded. The values were below the inherent accuracy of the instrument, as well as the strain cell used. Hence, it is difficult to assign stress values to these measurements.

Table 2 - Magnitudes of maximum and minimum stresses and the direction of maximum stress from doorstopper measurements, Detour Lake Mine.

| Depth below Surface | Test No. | Max. Stress (MPa) | Min. Stress (MPa) | Direction* of Max. Stress |
|---|---|---|---|---|
| 85 m (hanging wall) | DL1-2 | 9.68 | 2.82 | 21.9° |
| | DL1-3 | 0.53 | 0.43 | -9.2° |
| 60 m (footwall) | DL2-2 | 1.09 | 0.82 | 14.5° |
| | DL2-3 | 0.61 | 0.32 | 2.6° |
| 60 m (orebody) | DL3-1 | 1.38 | 0.65 | 94.5° |
| | DL3-2 | 2.51 | 1.75 | 28.5° |
| | DL3-3 | 3.78 | 2.21 | 41.5° |

* Angles counter-clockwise (positive) from horizontal E-W.

Table 3 - Stress components, magnitudes and orientations of the principal stresses from doorstopper measurements (test holes DL3, DL4, and DL5), Detour Lake Mine.

| Direction | Magnitude (MPa) | Standard Error (MPa) |
|---|---|---|
| East-West | 3.03 | 0.60 |
| North-South | 2.10 | 0.50 |
| Vertical | 1.52 | 0.59 |
| $\tau_{EN}$ | 0.27 | 0.21 |
| $\tau_{EV}$ | 0.29 | 0.41 |
| $\tau_{NV}$ | 1.53 | 0.56 |
| Residual sum of squares | $6.00 \times 10^{3}$ | |
| Standard deviation about fitted regression line | 0.12 | |

| Principal Stress | Magnitude (MPa) | Orientation (dir./dip) |
|---|---|---|
| $\sigma_1$ | 4.05 | 257°/32° |
| $\sigma_2$ | 2.04 | 348°/02° |
| $\sigma_3$ | 0.56 | 082°/58° |

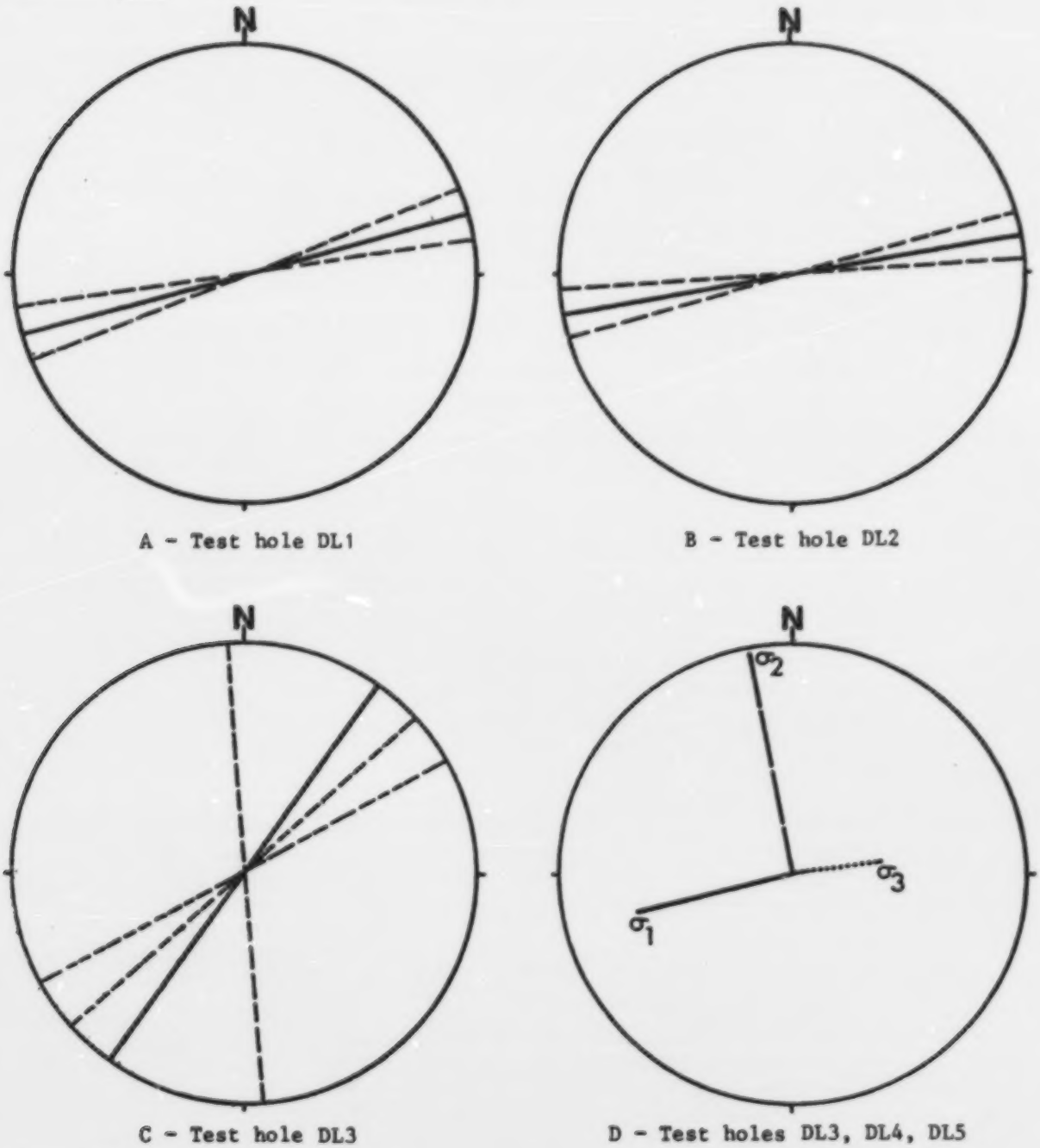



Fig. 4 - A, B, C: maximum stress directions in the plane normal to the drill hole axis; D: principal stress directions from stress determinations in three test hole set up, lower hemisphere of equal area net; (Grid north = True north).

## DISCUSSION OF RESULTS

The directions of the calculated maximum stresses for the three stress measurement sites show good agreement. An east to northeasterly trend is well pronounced. When comparing the results, the stress magnitudes indicated some scatter. However, in regard to the significant differences in elastic properties and the strengths of rock types encountered at the test locations, the variation in magnitude is understandable.

With respect to Mine grid north (= True North) the orientations of the principal compressive stresses are:

| Principal Stress | Direction | Plunge |
|---|---|---|
| $\sigma_1$ | WSW-ENE | 32° WSW |
| $\sigma_2$ | NNW-SSE | 02° NNW |
| $\sigma_3$ | ENE-WSW | 58° ENE |

The orientations of the principal stresses are found to be in good agreement with those obtained elsewhere in this region (5-8). The magnitude of the horizontal E-W stress is about 1.4 times the N-S stress, and the measured vertical stress component is comparable with the overburden pressure.

The major principal stress ($\sigma_1$) is oriented along the strike of the ore zone, while the intermediate principal stress ($\sigma_2$) is perpendicular.

## ACKNOWLEDGEMENT

The cooperation of Detour Lake Mine, and especially B. Kristof, Geological Engineer at Detour Lake Mine, who carried out most of the field measurements, is appreciated.

## REFERENCES


1. Goodwin, A.M. and Ridler, R.H., "The Abitibi orogenic belt"; in Symp. on Basins and Geosynclines of the Canadian Shield; A.J. Baer (Ed); Geological Survey of Canada, Paper 70-40, pp 1-30; 1970.

2. Leeman, E.R., "The CSIR 'doorstopper' and triaxial rock stress measuring instruments"; Rock Mech., No. 3, pp 25-50; 1971.

3. Herget, G. and Hedley, D.G.F., "Rock mechanics instrumentation - part III: stress determinations with overcoring techniques"; Division Report MRP/MRL 71-79 ID; CANMET, Energy, Mines and Resources Canada; 1971.

4. Davies, O.L., "Statistical methods on research and production"; Oliver and Boyd, London, U.K., p. 396; 1967.

5. Arjang, B., "Field stress determinations at Selbaie Mine, Quebec" Division Report MRP/MRL 84-55(TR); CANMET, Energy, Mines and Resources Canada; 1984.

6. Miles, P. and Herget, G., "Underground stress determinations using the doorstopper method at Timmins, Ontario"; Division Report MRP/MRL 76-148(TR), CANMET, Energy, Mines and Resources Canada; 1976.

7. Vongpaisal, S., "Stress measurements at Kiena Mine"; Internal Report; Kiena Gold Mines Ltd., Val d'Or, Quebec; 1983. Personal communication.

8. Herget, G., "Regional stresses in the Canadian Shield"; in Underground Rock Engineering, CIM Special Vol. 22, pp 9-16; 1980.